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E. W. HILGARD, DIRECTOR

LUPINS FOR GREEN-MANURING

By J. BURTT DAVY

Assistant Botanist



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INTRODUCTION.

GREEN-MANURE CROPS.

The Need for Green-Manure Plants.—The importance of returning to the soil of orchards and vineyards an amount of nitrogen at least equivalent to that removed by the fruit crop, and also the humus gradually burnt out during the dry season, in order to maintain fertility, has caused the Experiment Station at Berkeley to devote much attention to the testing of various leguminous plants—plants of the pea and clover family—recommended for this purpose in other parts of the world. While it is comparatively easy to find plants that will answer this purpose when or where summer growth can be allowed, as in the case of field crops, the selection of plants that will grow in winter so as to permit of being turned under before the summer's drought renders such growth too wasteful of moisture, is a matter of no little difficulty. The present bulletin is designed to give the most promising results thus far obtained, in order to promote large-scale experiments by farmers during the present and coming seasons.

Plants other than those of the leguminous order (clovers, peas, beans, lupins, etc.) are not recommended for green-manuring, for the reason that they supply to the soil only the humus, besides what substances they have taken from it during their growth; while yet, a leguminous crop costs no more than any other. It is true that in the case of all tap-rooted plants the surface soil is enriched by what was taken from the subsoil. But as in the arid region the surface soil is largely of less importance than the subsoil, on account of the deep rooting and feeding characteristic of plants in arid climates, the advantage thus secured is greatly reduced; as is also that of the crop roots being afforded an opportunity of deep-rooting by following the course of the tap-roots of the preceding crops. Moreover, nitrogen being the most expensive of elements supplied in manures, the advantage of securing it from the atmosphere without additional cost is obvious.

The legumes combine all the points required of a green-manure plant—nitrogen-absorption from the air, deep-rooting, and, at the proper stage of growth, that succulence which is conducive to quick

decay, thus rendering the crop-ingredients available at the earliest moment. Nevertheless, the plowing-in of other green crops or weeds, when convenient, should not be neglected.

It should be stated that the absorption of nitrogen from the air is conditioned upon the formation of excrescences or tubercles upon the roots; these being formed by the bacilli possessing that valuable faculty. When the soil is abundantly supplied with available nitrogen-compounds, tubercles may fail to form; and such failure may also result from the absence of the proper bacilli, rendering necessary the "inoculation of the land."

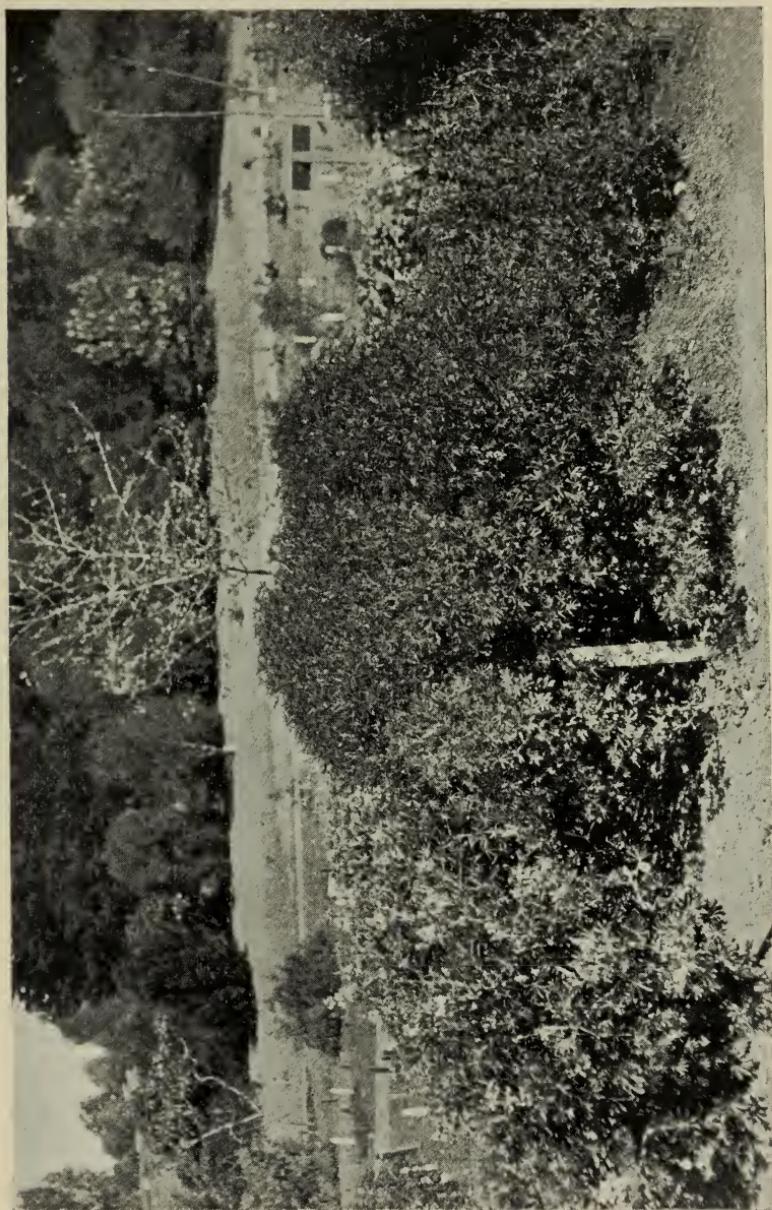
Peculiar Conditions Require Peculiar Plants.—The peculiarities of the climatic and agronomic conditions of arid regions make it largely impracticable to utilize the crops employed in humid regions. Our choice is ordinarily restricted to annual plants, which make a good winter growth and can be plowed under in spring (usually in March), so as to avoid the waste of moisture from summer growth; they must be adapted to calcareous soils; and must have stems not so woody as to resist fairly rapid decomposition.

It has been suggested that many of our native California species would prove better adapted to these conditions than introduced plants; but none of the numerous species so far tested for this purpose, have given entirely satisfactory results; they develop too late in the season; and are not always hardy against frosts.

Among the various leguminous crops so far experimented with at Berkeley, Bur Clover (*Medicago denticulata*), Square-pod Pea (*Lotus tetragonolobus*), and Snail Clover (*Medicago turbinata*), have given the most promising results; but none of them yield as heavy a crop as could be desired, and the two latter have not been found suited to all our climatic conditions.

For further information on the subject of green-manuring, the reader is referred to the Report of this Station for the year 1894-95 under the title of "Supply of Soil Nitrogen," pp. 32 to 35, and "Crops for Green-Manuring," pp. 118 to 123.

The Station has sent for a sufficient supply of seeds of the several kinds of lupins herein mentioned, for the distribution of small trial packets early in autumn. But as the success of some of the varieties mentioned for green-manure purposes is already definitely ascertained, it is hoped that the facts here given may induce some enterprising seedsmen, or private parties, to make larger importations from France and Germany for large-scale trials, which cannot fail at least to pay expenses, if they do not prove highly remunerative.



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Plate 1.—LUPINS IN THE BOTANIC GARDENS, BERKELEY, 1898.

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1. Pink Lupin. 2. Small Blue Lupin. 3. Yellow Lupin.

LUPINS FOR GREEN-MANURING.

By J. BURTT DAVY.

Discovery of the Adaptability of Certain Lupins.—In cultivating in the Botanic Garden a collection of Mediterranean-Region lupins for comparative botanical study, it was found that the spring-sown plants did not have time to reach maturity before the hot, rainless season dried them up. It was therefore determined to try fall-sowing, with a view to catching all the moisture available, thus inducing winter growth and deep-rooting. As a result of this experiment it was found that whereas the spring-sown plots were a complete failure, the fall-sown, in accordance with Italian experience dating back to the Romans, produced heavy crops and were so promising that it was determined to test the species on a more extensive scale, with a view to the adoption of the best of them for green-manure crops. The results of these tests are outlined in the following pages.

Though the most important use of lupins lies in their adaptability for green-manuring, they are also grown extensively in Europe for cattle-forage and human food, and as ornamental plants. (See p. 29)

DETAILS REGARDING THE SEVERAL SPECIES OF LUPINS.

1. *LUPINUS PILOSUS*, Linn.—This species is an annual and a native of the eastern Mediterranean Region (Grecian Archipelago, Syria, Palestine, etc.) It is readily distinguished from all other species known to us by its large, flattened, brown, bean-like seeds, nearly half an inch broad, of which the outer seed-coat is roughened with minute projections; the leaves are large and velvety, with broad leaflets; the flowers bracted.

The typical wild form does not appear to be in cultivation, but it has given rise to two cultural varieties, *L. pilosus caeruleus*, Hort. and *L. pilosus roseus*, Hort., both of which seem, from all available information, to be in cultivation in Italy and France, but probably only to a limited extent, as we find no mention of them in agricultural literature.

2. LARGE BLUE LUPIN (*Lupinus pilosus caeruleus*, Hort.) Plate 1—
Annual, flowers large, dark blue, with a white line down the center of the standard, which in age changes to dark purple. The seeds are heavy, there being only 760 to a pound of Berkeley-grown seed.



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Plate 2.—LARGE BLUE LUPIN.

1. At time of first flowering. 2. At time of second flowering.

Experiments at Berkeley.—For heavy, calcareous soils, this is undoubtedly the best of the species tested; it has shown no sign of root-rot, although species adjacent on all sides were affected; it is not injured by frosts at Berkeley, is more succulent than the varieties of *L. angustifolius*, produces more and larger foliage, and covers the ground better, branching more freely from the base. The size and heaviness of the seed would seem to be a disadvantage, but this is outweighed by the fact that owing to its branching habit, it requires more room in the rows, and the same weight of seed per acre will produce

one-third more manure than in the case of the Small White Lupin; so that the former species is in the end the cheaper of the two. It produces a larger number of well-developed root-tuberles even under the very adverse conditions which caused an absence of tuberles in all other species except No. 3 (the Pink Lupin).

Before branching it produces, very early in the season, a terminal flower-spike, and in this state is quite succulent. When the first pods form, the whole plant branches freely, and becomes somewhat woody; these branches flower much later than the main stem. Owing to this peculiarity it may be advisable to plow in the green-manure at the beginning of February, or, if conditions of soil and climate make this impracticable, then to sow from two to four weeks later in order to bring the period of first flowering nearer to plowing time, the plants being in the best condition for quick decay when the first flowers appear.

Experiments at Pomona.—Mr. Mills, foreman of the Southern California Sub-Station near Pomona, reports that at first this promised to be the best species under observation, but that the larvae of some insect attacked and destroyed a large number of plants and nearly killed the rest. The latter finally sent out branches which came into bloom when the plants were about eighteen inches high; they were again attacked by the same insect, which destroyed nearly all the flower-heads; the weight of seed finally produced was little more than the amount originally sown. This species was also damaged by the frost of March 23rd, 1898, at 7 a. m., when for half an hour the mercury stood at 27° F. At Berkeley it was not affected by the frost of Feb. 4, 1899, when the thermometer registered 29.9° F., and when several other plants, including the native *Lupinus affinis*, were injured.

3. PINK LUPIN (*Lupinus pilosus roseus*, Hort.) Plate 3.—An annual, closely resembling the preceding variety in general habit, size, pubescence, etc.; but the color of the flowers is pale pink, with a white line down the center which in age changes to magenta. The seeds are almost as heavy, there being 864 to a pound of Berkeley-grown seed. (See Plate 3 on following page.)

Experiments at Berkeley.—This variety has the same habit of growth as the preceding and like it, is not affected by frost or root-rot; but the tests this year indicate that in new soil, not inoculated with the lupin bacteria (see p. 25,) it will not always produce tuberles as readily as the Large Blue Lupin.

4. YELLOW LUPIN, (*Lupinus luteus sativus*, Hort.) *Lupinus luteus* of various authors; *L. odoratus*, Hort., Fragrant or Scented Lupin.



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Plate 3.—PINK LUPINS.

1. At time of first flowering. 2. Showing tubercles.
 3. At time of second flowering.

FRENCH: Lupin jaune, lupin odorant. GERMAN: Gelbe Lupine.

Annual, low-growing and much branched from the base; stem succulent; flowers rich yellow, very fragrant.

The wild plant of which this is a cultivated variety is a native of the Mediterranean Region.

Uses.—The Yellow Lupin has been grown since 1840 as a forage plant in parts of Germany (Saxony, Silesia, Pomerania, Bohemia, Moravia and Brandenburg) and of France (Boulogne, Manche and Bourbonnais.) It is also said to be grown in some parts of England, and in Norway as far north as 70° latitude.

It is the least bitter of the cultivated lupins, but animals are said not to care for it in a green state, and it is usually made into hay. At present, however, it is extensively cultivated as a green-manure,

to improve the poor sandy soils found in parts of Prussia and of France; for this purpose it is considered the best of all the species tried there, and will thrive even on drift-sands of the sea coast. Langenthal observes that what the Sainfoin is for the poorest limestone or marly soil, the Yellow Lupin is for sandy land. As a green-manure it is considered superior to the Small Blue Lupin, because the roots penetrate the soil to a much greater depth, and because rye is found to succeed much better after the Yellow than after the Small Blue Lupin; wherever possible, therefore, the former is grown in preference to the latter; as far as Europe is concerned, it is more extensively grown than any other species. Kette observes that this species shows an advantage over the others in never being choked by weeds if the soil is at all suitable.

Soils.—Heuzé states that it will not succeed in impermeable or calcareous soils, but that it grows well in deep sandy, and light and ferruginous soils, and forest lands which have lost their acid character; it is not grown on clay soils. Werner notes that it does not do as well as the Small Blue Lupin on gravelly or marly soils. Our own observations show that of all the species tried at Berkeley, this is the most difficult to grow in heavy, strongly calcareous adobe soils, partly owing, doubtless, to their impervious character; for the seeds germinate readily and the plant makes a good stand when the soil has been dressed with stable manure.

Cultivation.—In France it is customary to sow from 70 to 110 lbs. of lupin seed to the acre. In Hanover the following rotation is often practiced: With the last hoeing of the potato crop, from the end of April to the middle of May, lupin seeds are dropped between the rows of potatoes. In the fall the potatoes are harvested and the lupins plowed under. Rye or winter wheat is then sown, sometimes immediately after plowing, without any bad results (Kette); though oftener fourteen days are allowed to intervene. After the grain harvest, in the following August, the land is again plowed and lupins are sown for a winter crop, which is plowed under in the spring and is followed by a crop of oats. When grown for seed the Yellow Lupin is harvested at the end of August.

Experiments at Berkeley.—For three successive seasons this species has proved a failure in the strongly calcareous adobe soil at Berkeley, except when treated with stable manure; in which case, however, though it made a fine growth of succulent matter, scarcely any tubercles were produced, showing that the nitrogen was derived from the soil. There is little doubt that if sown early enough this species would prove very beneficial on our light, non-calcareous soils, and it should be tried in the granitic and red soils of the Sierra

Nevada foothills, and the sandy soils on the plains at the foot of the Tehachapi and the Sierra Madre ranges. It has not been affected by frost or root-rot. It is much later in time of flowering than either of the varieties of *L. pilosus* or of *L. angustifolius*, not coming into bloom till the second week of March. The table on p. 28 shows the yield of green material to be very poor; but this is due to the fact that in this instance few seeds germinated and but very few plants came to maturity, doubtless owing to the soil conditions. In manured soil, where all the seeds germinated and the plants attained good height, the weight of green material was much greater.

5. SUCCULENT LUPIN (*Lupinus affinis*, Agardh).—A rather low (2 to 2½ feet high), much branched, succulent annual; flowers purplish, seeds medium-size. Indigenous to California, growing luxuriantly on sloping adobe or clay banks, from Marin County southward to San Diego.

Experiments at Berkeley.—We are not aware that this species has been tried, either for forage or for green-manure, except in California, and with us it has proved unreliable in germination, slow in coming to maturity, and less resistant to frost than the foreign species. Several plants were cut to the ground in the cold snap of February 4, 1899 (29.9° Fahr. at the University observatory, and probably still lower on the low ground), when the European species were not affected.

Lupinus affinis ranks next to *L. luteus* in succulence, but does not decompose as thoroughly nor as rapidly. Although its germination is unreliable, yet under cultivation it shows a tendency to improve in this respect. It produces a heavy crop of seeds. Under steady cultivation this species is likely to prove a valuable plant for green-manure in *frostless* regions; it produces an abundance of tubercles both in new soil and in soil which has been manured. On this account, and because of its heavy yield per acre and great succulence, it is worthy of more attention.

6. NARROW-LEAVED LUPIN (*Lupinus angustifolius*, Linn.)—In modern Greece called "agri lupouni," and in Egypt "termis el Sjaeitan" (Satan's Lupin), possibly on account of its habit of springing up as a weed among crops of cultivated lupin, like the tares of the Scripture parable.

Annual, branching from the base, about 1½ feet high; leaflets narrow; flowers small, pale blue; seeds ovoid, smooth, mottled with gray and white. Not in full flower till the middle of April.

This is the typical wild form, a native of the Mediterranean Region of south Europe and north Africa, where it occurs as a weed in grain-

fields. We first find mention of it about 306 B.C. It is supposed to be the plant spoken of by Dioscorides as "thermos agrios," and the "lupinoun agrestum" of the Romans. It does not appear to be now cultivated for agricultural purposes, but from it have been obtained the valuable varieties called respectively *caeruleus* and *diploleuca*, the Small Blue and the Small White Lupin.

Naudin says that sheep are pastured on it in places where it grows wild. It is said to prefer sandy, poor soils, and appears to dislike excess of lime.

Experiments at Berkeley.—During three successive seasons we have found *Lupinus angustifolius* much less reliable than the two succeeding varieties; it does not germinate well in our calcareous soil, makes an unequal stand, and is shorter and slower of growth. It branches much more freely from the base than its varieties, but like them it lacks the succulence of some other species. It is liable to infection with root-rot. The stems do not decompose readily: after being plowed under and remaining a month (from March 18 to April 22, 1899), they were still long and fibrous. This species produces but few tubercles, and is late in flowering.

7. SMALL BLUE LUPIN (*Lupinus angustifolius caeruleus*, Körn). Plates 4 and 5.—GERMAN: Blaue Lupine; FRENCH: Lupin bleu, lupin à fleurs bleus, petit lupin bleu.

Closely resembling *L. angustifolius*, of which it is only a cultural variety, but taller (3 feet), not branched from the base, and with flowers of a brighter blue. It is in full flower early in March. A somewhat woody-stemmed variety. As to when and where it originated we appear to have no record; it is probably the plant referred to by Tournefort, in 1700, as "*L. angustifolius caeruleus elatior*." It was first cultivated in Germany for green-manure in 1830.

Uses.—It is now grown extensively for green-manure, both in Germany and France, especially about Bordeaux (Kette). According to Cornevin it was more largely grown in France in former times than at present, being used for feeding sheep; it has been neglected for this purpose of late years, on account of its poisonous qualities (see p. 29). Langethal considers that it is of small value as green forage, on account of the hardness of its stems, but that the large amount of seeds produced, which are also fed to stock, renders it a valuable crop.

Soils.—Werner states that on gravelly and marly soil the Small Blue Lupin gives better results than the Yellow Lupin. It is fairly tolerant of limy soils in California, but less so than the varieties of *L. pilosus*. Langethal notes that it grows very well on a stiff and even

a clayey soil which is sufficiently broken up by repeated plowing; in this respect it is superior to the Yellow Lupin. Werner states that the seeds of this species lose the power of germination more rapidly than those of *L. luteus*, but they are easier to collect, not falling out of the pods as readily as they do in that species.

Experiments at Berkeley.—At first this gave promise of being the species best adapted for green-manuring in middle California; it germinates readily, and makes an excellent stand in our calcareous, blackish adobe soil, is not affected by frost and is a rapid and robust grower. It does not, however, branch well from the base, and fails to rot quickly and thoroughly after ploughing under. During the present season it has been badly affected by a root-rot, which has in some rows destroyed from 50 to 75 % of the plants, especially in the late-sown plots. The effect of early sowing on the yield of green material is admirably shown on plate 1, the large plants having been sown at the end of September, and the smallest ones, (photographed at the same time and on the same plate,) were sown November 17th.

Chino Valley.—Mr. Mills reports for 1897-98 that at the Southern California Station it came up in good season after planting, and promised to make a good growth; it was badly damaged, however, first by hares, then by the heavy frosts of March 23rd, and finally by root-rot. This species early produces a very long tap-root in the Pomona soil, as is well shown on the plate. For the season of 1898-99 Mr. Mills reports that although the plants were frozen stiff, clear to the ground, by the heavy frost of February 6th, they showed no bad effects after thawing out. He considers that if the ravages of root-rot can be successfully combated by treating the seed or by any other means, this species will be pre-eminently the best for the uncertain seasons of southern California.

Sierra Foothills.—The Small Blue Lupin appears to be absolutely worthless on the granitic and red soils of the Sierra foothills at Jackson, Amador Co. With a rainfall of twenty-six inches, plants raised from seed sown October 24th and 25th, 1898, had only attained a maximum height of eight inches by April 20th, 1899, at which time they were setting seed. Much the same result is reported from Anaheim, Orange Co.; but in both cases it may have resulted from the late sowing.

8. SMALL WHITE LUPIN (*Lupinus angustifolius diploleuca*, Körn.)
GERMAN: Ostpreussische weisse Lupine. Scarcely differs from the var. *caeruleus*, except in having white flowers and white seeds.

Kette states that since 1881 this plant has been increasingly grown in Germany for forage, as a substitute for the Small Blue Lupin,



Plate 4.—SMALL BLUE LUPIN. BERKELEY.



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Plate 5.—SMALL BLUE LUPIN. POMONA.

1. Sown November 17. 2. Sown September 28.

3. Thirty day seedling at Pomona. 4. Thirty day seedling at Pomona of *L. pilosus*.

because the seed is less injurious to cattle than that of the latter variety.

In California there is no difference noticeable as to the growth of the plant; it appears to be equally susceptible to root-rot.

Southern California.—Mr. Mills reports as follows for 1897-98: "Sown October 19th, sprouted November 1st, it came up in good season after planting, and promised to make a growth that surpassed that of any other variety; but the hares made a dead set on it, and before we could get the batch of invaders killed off, they had cut off the central stem of all the plants, and they lost considerable valuable time. They then sent out lateral shoots, but again lost considerable time when they would otherwise have made their best growth, for the heavy frost on March 23rd killed the greater part of the flower-spikes. It finally matured seed when about two feet high. It would undoubtedly be the best of the species tested, if given a fair start, and with normal conditions of weather."

9. **LARGE WHITE LUPIN** (*Lupinus albus*, Linn.)—*Lupinus albus vulgaris*, Alefeld. **GERMAN**, Weisse, Dünghupine, Gewöhnliche weisse Lupine. **FRENCH**, Lupin blanc, pois lupin, pois de loup, or fève de Loup. **ITALIAN**, Lupino, and **PORTUGUESE**, Tramoso.

Not unlike *Lupinus pilosus* in habit, but the flowers are white, without bracts; upper lip of calyx entire; seeds smooth, white.

The Large White Lupin is apparently a native of Italy and Sicily; it also occurs in a wild state, but perhaps naturalized, along the eastern coast of the Mediterranean and as far east as the Caucasus.

History.—It appears to have been grown in Egypt at a very remote period of antiquity. It is considered to be identical with the "lupinus" of Cato, Varro, Virgil, Columella, Pliny and Palladius, and the "loupinoum" of Dioscorides. The Greeks and Romans cultivated it as early as 396 B.C. for green-manure, as well as for the seeds. The occurrence in Spain of four common names for this plant, differing according to the province, indicates, according to De Candolle, its very early cultivation in that country. In Germany it was first cultivated in the Rhine provinces, in the 16th century, for green-manure only; in Austria in the 17th century, and in Saxony in the 18th century. In Italy it was being very largely grown in the 18th century.

In recent times the Large White Lupin has been cultivated in Egypt, Greece, Italy, Spain, Portugal, southern France and Germany. It is not much grown in northern France, being subject to injury from frost. In southern France it can endure a temperature as low as 10° C., (14° F.) if sown sufficiently early in the fall; in the north of Europe, on account of frost, it is not sown before the middle of April,

does not flower before the end of August, and fails to ripen seed (Kette.)

Uses.—In some parts of Italy it is used as a mulch around the olive trees. The French grow it to improve the quality of their poorest lands. In Germany it has been considered a good green-manure, as it yields a large quantity of foliage; but latterly it appears to have fallen into disuse, and to have been superseded by the Small White Lupin.

Naudin states that in Spain and Portugal the Large White Lupin is considered a good and nourishing forage plant; Vesque considers, however, that its foliage is too bitter to serve for this purpose. De Candolle states that the seed is good fodder for cattle, but in Germany it has been found that cattle dislike both leaves and seeds. In Portugal, according to von Mueller, it is highly esteemed, under the name of Tramoso, as a remedy against pernicious and obstinate weeds, especially Sorrel (*Rumex Acetosella*, Linn.) on account of its close and early growth.

The seeds, boiled to deprive them of their poisonous properties, were sold for human food in the streets of ancient Rome, and were also used for food by the ancient Egyptians and Greeks. They are still so used by the inhabitants of Andalusia, Corsica, Piedmont, Spain, and Portugal, according to Cornevin.

Soils.—In southern Europe the Large White Lupin is grown almost exclusively on sandy and siliceous soils. In Germany, von Wulffen cultivated it only on a warm sandy soil, and found that marling did not perceptibly increase the yield. Dr. Pabst found that it would make a growth, though only small, on a loamy, sandy soil, which contained much lime and magnesia, and on which the Yellow and Small Blue Lupins always failed; so that, though susceptible to calcic carbonate, it seems to be less so than those species (Werner).

10.—EGYPTIAN LUPIN (*Lupinus Termis*, Forsk.).—*L. albus Termis* Alefeld; *L. prolifer*, Desrouss.: Sicilian, Roman or Neapolitan Lupin: GERMAN, Weisse Futter-Lupine, Aegyptische or Sicilianische Lupine, Römische Lupine, Sprossende Lupine: EGYPTIAN, Tharmos: ARABIC, Termis or Termus.

Described as very closely resembling *L. albus*, but taller and branching from the ground; keel blue, darker at the tips; seeds larger, only 305 to a pound of German-grown seed; flowers later. In Germany, it does not ripen seed till October.

It is found wild on some of the islands of the Mediterranean, was cultivated by the ancient Egyptians, and is still cultivated in Egypt, Greece (Boissier), Crete (De Candolle), and Germany (Kette).

Uses.—In Germany it is said to yield a large amount of green forage, but the stem becomes woody towards autumn. In Egypt the seeds are eaten, after steeping to remove the bitterness, and they are even exported to India (though not cultivated there) and sold in the bazaars under the name of *tourmus* (Royle). We have no record of its having been used for green-manuring; it may prove too woody for this purpose.

Soils.—Kette observes that the Egyptian Lupin is less susceptible to lime than *L. luteus*; he considers that the soil best adapted to it is a sandy loam, or a loamy sand; a small quantity of lime carbonate in the soil seems to have a beneficial influence in shortening the period of growth. He observes that in uncultivated, sandy soil, where the Yellow Lupin attained a height of 2 feet, the Egyptian Lupin was only 6 inches high; while in cultivated soil it attained a height of 4 feet, and on manured loamy soil a height of 7 feet. Manure is said to cause a greater increase in yield in the case of the Egyptian Lupin than in the case of the Small Blue or the Yellow Lupin.

11. CRUICKSHANKS' LUPIN (*Lupinus Cruickshanksii*, Hook).—*L. mutabilis*, Lindley, not of Sweet.

A tall, woody annual, native of Chile and Peru, and long cultivated as an ornamental plant; the flowers are very handsome, the standard being white, streaked with purple on the margins and with a yellow spot in the center; in age the white standard changes to purple. In recent years it has been grown for forage in Germany, and it is said that cattle prefer it to the Yellow Lupin, especially if mixed with clover. German writers state that it needs a good soil if side shoots are to be formed, but that if the soil be too rich it will not make much seed.

At Berkeley all but two of the seeds germinated readily in the season of 1897–98, but were killed by a hot north-east wind just after the cotyledons appeared above ground. The two more tardy seedlings survived, however, and one produced seed from which the present crop has been raised. This year (1898–99) it has made a good growth; but has not produced tubercles, as it was sown in manured soil. Doubtless it will produce tubercles in unmanured soil, but it does not appear promising for green-manure, as the stems are rather woody. Our plants made very few side-shoots below, though the soil was rich, but branched well from above. Another season's test is necessary before its value can be ascertained.

12. THE TRICOLORED LUPIN (*Lupinus tricolor*, Hort.), of south European gardens, has been tried at Berkeley, but without very satisfactory results so far. It is less tall and more branched below than

the preceding species. The flowers are at first very light-colored, the standard being pale lavender and the wings pure white; after a few days the color of the standard gradually deepens to rich purple, and that of the wings to a lighter tint of the same.

13. PERENNIAL LUPIN (*Lupinus perennis*, Linn.)—Perennial; rootstocks creeping; stem branching very freely, covering the ground; flowers pale bluish-purple; seeds very small. Flowering period, May and June.

Native of the eastern United States, from Canada to Florida. Cultivated in Germany as a forage plant, and found less objectionable to cattle than the Yellow Lupin. It requires a good soil, retentive of moisture and clayey, because the creeping rootstocks draw their moisture from the surface, not reaching down to the subsoil; on this account Langethal considers that it may prove a valuable substitute for other leguminous crops in places where the surface soil is good but the subsoil poor, as in some of the hilly parts of middle Germany. It begins to grow early in the spring, and according to Langethal "will be 4 inches high by the time the apples are in bloom." Several crops can be obtained in a season, the first of which is ready early in June.

We do not find any record of its having been grown for green-manure; perhaps the creeping rootstocks make it unsuited for this purpose, as plants with this habit are usually plowed under with difficulty, and pieces of the root continue to grow long after the time when the orchard or vineyard should be clear of weeds, to prevent undue loss of moisture by their transpiration.

14. HAIRY LUPIN (*Lupinus hirsutus*, Linn.) *L. digitatus*, Forsk.—Annual; reddish-hairy; flowers blue; seeds somewhat flattened, grayish-brown, smooth.

Native of the northern shores of the Mediterranean, from Spain to Asia Minor. Cultivated extensively in Germany as an ornamental plant, it has also been tried as forage, and it is said that the cattle prefer both the green parts and the seeds to either the Small Blue or the Yellow Lupin. It has a disadvantage in that it does not flower till July (in Germany), and the seeds ripen late. The pods open too easily, making it difficult to collect the seed. It requires a good soil, and apparently will not thrive on the poor sandy soils on which the Yellow Lupin does so well.

CULTIVATED SPECIES OF LESS IMPORTANCE.—The Greek Lupin, *Lupinus Graecus*, Boiss., and the Netted-seeded Lupin, *L. reticulatus*, Desv. (*L. linifolius*, Roth.), are also mentioned as being in cultivation to a limited extent in portions of southeastern Europe, but we

have no definite information about them, except that the latter is not considered to possess any advantages over the Small Blue Lupin.

CALIFORNIA SPECIES WHICH HAVE PROVED UNSATISFACTORY.—The following annual species have also been tried at Berkeley, but without success; they are all natives of California: *L. nanus*, Dougl.; *L. polycarpus*, Greene; *L. pachylobus*, Greene; *L. leptophyllus*, Benth.; *L. truncatus*, Nutt.; *L. microcarpus*, Sims.; *L. densiflorus*, Benth.; *L. luteolus*, Kellogg.

BITTER MELILOT (*Melilotus indica*, All.)—Though not by any means one of the Lupins, yet on account of the importance of the subject of green-manuring at the present time, it has seemed best to take this opportunity of bringing the plant to the notice of agriculturists. Prof. A. J. McClatchie, of the University of Arizona Experiment Station, at Tucson, writes under date of April 27th, to the effect that in Arizona this plant is found to be the most successful green-manure crop that can be raised in their orchards. He continues: "the conditions are somewhat different with us than with you. Ordinarily we have plenty of irrigating water to grow anything we choose, until as late as April at least. Before that time the *Melilotus* makes a fine growth. We began plowing ours under about the first of April, the yield being 15 to 16 tons of green matter per acre, or 2½ to 3 tons of dry matter. Nothing else that we have tried will approach this in yield during the winter."

Reference to table 1 (p. 26) shows that this yield is less than that of either the Pink or the Large Blue Lupin, and only just above that of the Succulent Lupin. At the same time the leaves of the Bitter Melilot are small and sparse, and the stalk is very woody; by far the largest part of the weight, therefore, is probably fibrous matter, unfitted for rapid decomposition, and of a nature to keep the soil perhaps too loose and dry; both disadvantageous features. On the other hand, the hold which this plant has acquired upon California as a weed, the readiness with which it can be obtained and with which it will grow, the small size of its seeds, and the fact that it will flourish and develop a fine mass of tubercles in alkali soils, are points which make it worthy of further consideration. As in California it makes but little growth in winter, it could not replace the lupins for orchards and vineyards.

SUMMARY.

Thirteen species or varieties of lupin are more or less extensively cultivated as agricultural crops in various parts of Europe and north Africa; of these, eleven are natives of Europe, one of Chile and Peru, and the other of North America. Seven of the most important species

have been the subject of investigation at Berkeley in the last four years, but some of them only during the present season.

In addition, ten annual native Californian species have been under cultivation in the Botanic Garden at Berkeley for seven years; only two of these, however, *Lupinus affinis* and *L. micranthus*, promise to be of any agricultural value.

SPECIES RECOMMENDED FOR GREEN-MANURING IN CALIFORNIA.—For heavy, strongly calcareous soils in middle California, such as the adobe lands, the Pink Lupin (*L. pilosus roseus*) and the Large Blue Lupin (*L. pilosus caeruleus*) are much the best of the various species tried at Berkeley. Though the seeds of these two species are few to a pod, large and heavy, and are therefore more expensive than those of any of the other species tried, an equal weight of seed will produce a larger amount of green material than in the case of the others, (compare the *L. angustifolius diploleuca* and *L. pilosus caeruleus* on the table on page 26, where the weight of seed sown is the same, while the yield of the latter species is one-half as much again). For the Chino Valley, Mr. Mills considers the Small Blue Lupin (*L. angustifolius caeruleus*) to be pre-eminently the best species, if the ravages of root-rot can be successfully checked.

For the light, non-calcareous soils, the Yellow Lupin (*L. luteus sativus*) would undoubtedly be the most satisfactory, as it is so much less woody than any of the other species, and rots so much more quickly and thoroughly.

CULTIVATION.—The success or failure of European Lupins depends almost entirely upon sowing sufficiently early to catch the first rains, and at a time when the soil is yet warm enough to stimulate germination and prevent the rotting of the seed. If sown the last of September the Pink and Large Blue Lupins are ready to plough under by the first of February, and the Yellow by the middle of March.

In Germany, where a crop of rye usually succeeds lupin, it has been customary to allow about fourteen days to elapse between plowing in the lupin, and sowing the new crop, in order to allow the former to rot. Von Wulffen finds, however, that this is not necessary, and in France it is customary to sow immediately after plowing. Von Wulffen states that the green crop can be plowed under either just before, during, or after flowering.

Lupins as well as other leguminous plants do not, as a rule, make tubercles in soil freshly manured with stable manure; the manure is injurious to the tubercle-forming bacteria. This does not prevent the lupins from making a good growth, however; indeed they will often become very rank in manured soil, but the manure tends to check the

formation of seed. We can readily see, therefore, that it is a needless expense to manure land for lupins, or to sow lupins on land already manured, as the presence of stable manure prevents the accomplishment of the chief end for which they are sown, viz: the collection of nitrogen from the air by means of the bacteria on the roots.

SOIL-INOCULATION.—Where lupins do not grow wild or have not previously been cultivated, it is sometimes necessary to inoculate the soil, in order to secure a satisfactory growth. By inoculation we mean in this case, the transfer of small quantities of soil in which lupins have been grown, to the plot in which it is wished to cultivate them. The necessity for this inoculation arises from the circumstance that the bacteria peculiar to lupins do not make tubercles on plants of any other leguminous genus, and therefore are not found in soils in which lupins have not grown.

For successful inoculation, Professor Hilgard recommends the use of lupin soil taken from the first six inches, in the proportion of about a half ton to the acre. It should be spread lightly over the surface, immediately after receipt, and then be harrowed or cultivated in without delay, to prevent drying out, which would destroy the life of the bacteria.

SOILS.—In a communication to the *Landwirtschaftliche Presse* of Berlin, written last summer, Professor Hilgard points out that where lupins will suffer from the presence of 0.46% of calcium carbonate in sandy soils, as shown by Heinrich, they will tolerate twice as much in heavy clay soils.

ROTTING.—On March 18th. of this year a portion of the plots under observation at Berkeley was turned under to determine the relative rotting capacity of the different species. On April 22nd the rows were opened, with the following results, numbered according to degrees of decomposition:

1. Yellow Lupin, thoroughly rotted.
2. Succulent Lupin, } A considerable amount of fibrous matter left, but
3. Small White Lupin, } less than in any of the succeeding species.
4. Pink Lupin, } Not so good as 2 and 3, but better than Nos. 6
5. Large Blue Lupin, } and 7.
6. Small Blue Lupin, } Foliage well rotted, but stems still very fibrous.
7. Narrow-leaved Lupin, }

METHOD OF SOWING.—Mr. Mills reports from Pomona: "The drill system seems to be the only practical method of putting lupin seed in the ground where irrigation is contemplated. By using a beet drill the seed can be planted with little expense, fifteen or twenty acres being an average day's work in an orchard. The cultivator used with a beet outfit can be used both for preparing the ground for irrigation, and

TABLE I.—Comparative table of cultures of various Lupins at Berkeley.
Seeds sown in plot 8x5½ feet ($\frac{1}{9}\frac{1}{6}$ th part of an acre) September 28, 1898.

	LARGE BLUE.	PINK.	YELLOW.	SUCCE- LENT.	NARROW- LEAVED.	SMALL* BLUE.	SMALL WHITE.
Number of seeds to 1 lb.	760	864	.....	.....	.....	2,944	2,528
Amount sown per plot	1½ oz.	2½ oz.	½ oz.	½ oz.	½ oz.	1 lb., 1½ oz.	1½ oz.
Equivalent of seed in lbs. per acre	92, 13	154, 11	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.
Date of sprouting	Oct. 10	Oct. 10	Oct. 10	Oct. 10	Oct. 8	Oct. 10	Oct. 8
Commenced flowering	Jan. 4	Jan. 25	Mch. 8	Feb. 8	Feb. 8	Mch. 22	Feb. 22
Full flower	.....	.....	.....	.....	.....	Ap. 15	Mch. 7
Height of plant, in inches, on March 15	26	26	13½	24	18	36	37
Yield of green stuff, in lbs., free from soil, on $\frac{1}{2}$ plot (4x5½ ft., or $\frac{1}{9}\frac{1}{6}$ th part of an acre; weighed March 18, 1899)	19½	17	8½	14½	4½	10½	13½
Equivalent in lbs. per acre	38,115	33,660	17,325	29,205	8,910	20,295	26,235
Equivalent in tons per acre	19	17	8½	14½	4½	10	13
Equivalent on the basis of 100 lbs. lbs. of seed sown per acre.	41,066	21,760	56,000	94,400	28,800	17,041	28,267
in tons	20½	10½	28	47	14½	8½	14

* Plat 20x20 ft., $10\frac{1}{3}$ acre.

† Usually about two weeks later.

TABLE II.—Comparison of weekly growth at Berkeley.

Height of plant, in inches, on—	LARGE BLUE.	PINK.	YELLOW.	SUCCE- LENT.	NARROW- LEAVED.	SMALL BLUE.	SMALL WHITE.
October 17	2	1 $\frac{1}{2}$	1 $\frac{1}{2}$	(15th)	1	(15th)	2
October 24	4	3	2	(22d)	2	(22d)	3
October 31	4	4	2	(29th)	2	(29th)	4
November 6	6	4	3	(31st)	3	(31st)	5 $\frac{1}{2}$
November 14	6	5	3	(4th)	2	(4th)	6 $\frac{1}{2}$
November 21	6	5	3	(12th)	2	(14th)	7 $\frac{1}{2}$
November 28	6	5	4	(14th)	4	(12th)	8
December 5	6	6	4		5	8	
December 12	7	6	4		5	9	
December 19	7	6	4		5	9 $\frac{1}{2}$	
January 4	8	6	4		7	10	
January 11	10	7	4		7	11	
January 18	12	9	4 $\frac{1}{2}$		9	12	
January 25	13	12	5		11	13	
February 1	17	15	6		14	14	
February 8	18	16	6		14	15	
February 15	20	18	7		18	16	
February 22	24	18	9 $\frac{1}{2}$		21	17	
March 1	25	22	11		23	21	
March 8	26	24	13		23	23	
March 15	26	26	13 $\frac{1}{2}$		24	26	

TABLE III.—Comparison of yield per acre of various lupins.

SPECIES.	POUNDS OF SEED SOWN PER ACRE.	YIELD OF GREEN-MANURE PER ACRE.	TUBERCLES, MARCH, 1890, (in poor soil.)	AFFECTED BY DISEASE.	REMARKS.
<i>L. angustifolius</i>	30 lbs. 15 oz.	4½ tons (8,910 lbs.)	Few, often none.	Liable to infection.	Covers ground well, but unreliable in germination; woody.
<i>L. angustifolius</i> . caeruleus..... }	119 lbs. 1¾ oz. 92 lbs. 13 oz. }	10 tons (20,295 lbs.) 13 tons (26,235 lbs.)	Scarce, often none. Scarce, often none.	50-70 per cent. Many plants affected.	Very reliable; makes good stand, but does not cover ground well; is too woody. Same as <i>L. pilosus caeruleus</i> .
<i>L. luteus sativus</i>	30 lbs. 15 oz.	8½ tons (17,325 lbs.)	Few.	Not affected.	Covers ground well, and is very succulent, but unreliable in soils rich in lime.
<i>L. affinis</i>	30 lbs. 15 oz.	14½ tons (29,205 lbs.)	Many.	Not affected.	By far the best species for non-calcareous soils.
<i>L. pilosus roseus</i>	154 lbs. 11 oz.	17 tons (33,660 lbs.)	Few.	Not affected.	Covers ground well; the most succulent of all species tried, but somewhat unreliable and subject to frost.
<i>L. pilosus caeruleus</i>	92 lbs. 13 oz. (Compare with <i>angustifolius diplolecoea</i>)	19 tons (38,115 lbs.)	Very numerous.	Not affected.	Covers ground well, but is more woody than some species, and in new soil does not always form good growth of tubercles.
					The best species of any tried; being somewhat woody it may need plowing-in earlier or sowing later, or it may be necessary to mow with a reaper before plowing; makes good tubercles, even in new soil.

for cultivation afterward. The regular duckfoot attachment that goes with the machine, if bent slightly backward, will make an excellent furrower. By mixing corn, cracked to prevent germination, with the lupin seed, the latter can be distributed along the rows at any distance desired. The lupin seed being much heavier than cracked corn, a mixture of half and half by weight, would require a comparatively small outlay for corn, to make the seed go over two or three times the area that it would if planted alone." Mr. Mills recommends light sowing, both for a green crop and for seed, as close planting encourages the spread of disease and prevents the "setting" of seed in all the pods, which is not counterbalanced by the increase in number of plants.

Use of Lupin Seeds for Human Food.—The seeds of many—perhaps all—species of lupin contain a bitter alkaloid known as *Lupinin*, which is very poisonous to human beings. This bitter principle can be removed, however, by boiling, or by maceration in salt water or soda solution; in this state the seeds were used for human food by the ancient Egyptians, Greeks and Romans, and they are still so used in India (imported from the Mediterranean) and in Corsica, Piedmont, Spain and Portugal.

Use for Forage.—Although the foliage and seeds of lupins are bitter, they are grown for forage purposes in several parts of Europe. The species which are least bitter are the Yellow and Cruickshanks' lupin; the former is the one most commonly grown for this purpose on poor sandy soil in southern Europe. On heavy soils, unsuited to the Yellow lupin, the Small Blue lupin formerly took its place; this species is more bitter than the Yellow lupin and was found to be injurious to cattle, it has therefore been abandoned in recent years and its place supplied by the less noxious Small White lupin. The Large White and Egyptian lupins are said to be grown for forage to a small extent in southern Europe, but are generally considered too bitter for this purpose.

The foliage of the Yellow lupin is said to be not inferior to that of clover, and at the same time more bulky; indeed one writer states that, "when cut just at the end of flowering it is the most highly nutritious of all coarse fodders"; the seeds, also, are very fattening when used as an addition to ordinary fodder, and are said to be quite equal to oilcake. In Germany the average yield of air-dry forage is from 3,640 to 4,550 lbs. per acre, but in deep, new, sandy soils it is said to yield 5,460, 7,880 and even 9,100 lbs.

Lupin fodder is said to be fed either green or in the form of hay, but more frequently in the latter condition owing to its bitterness when green.

It is found to be unsuitable for feeding alone, as it then produces the disease called *lupinose*. Cornevin states that lupinose is particularly severe when stock are fed almost exclusively on lupin chaff, only mild when hay, oilcake or mangel-wurzel form a certain proportion of the ration, and it is given at intervals. In Germany it has been found that sheep will be affected with lupinose if supplied daily, without interruption, with 500 grammes (17 ounces) of the plant, including well-formed pods and seeds, or 300 grammes (10 ounces) of empty pods, or even with only 100 grammes (3½ ounces) of seeds. Drying does not affect the poisonousness of the plant, and the race, sex or age of the animal appears to make no difference as to its susceptibility. Sheep, cattle, horses, goats, dogs and tame rabbits are subject to the disease.

Lupinose appears in two forms, acute or chronic, and is accompanied by lack of appetite, difficult respiration, high fever, spasm and sometimes vertigo, resulting in death in the first case in four to six days, in the second in fifteen to twenty days. These symptoms, it will be noted, are quite similar to the "loco" of western pastures.

The Yellow lupin is considered much more poisonous than the Large White, and the Perennial lupin less so than any other species. In using *any* species for forage, great care must be taken not to use too much at a time, especially of the seeds, and not to use a lupin ration without intermission. In the event of any cases of lupinose appearing, the use of lupin should be abandoned entirely. Lupin should never be used exclusively in a ration.

For forage purposes the lupins, therefore, do not appear to offer any advantages over other leguminous crops, except as winter growers, and they are certainly more or less dangerous and not to be recommended indiscriminately.

NOTE.

Since the above was in type, a letter from the Foreman of the Paso Robles station informs us that the *Lupinus affinis* (as determined by the Department of Botany) is of common and heavy growth in the Willows Creek District, twelve miles west of Paso Robles. The plants were found to have an average height of three or four feet, and twenty of them weighed twenty-four pounds.

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